MAINTENANCE OF A GIVEN STATIC FORCE WHILE THE FORCE OF GRAVITY IS TRANSFORMED*

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Previously we carried out an experimental investigation of certain indices of coordination of human motions when the human being was subjected to alternating stresses and weightlessness [1—3]. The experiments were carried out during jet aircraft flights along a weightlessness parabola; over certain segments of this parabola the g-forces reached 2-2.5 for a period of 10-12 sec and weightlessness lasted 17-23 sec. In each flight 4-8 parabolas were traversed.

During the flight the test subject was held by a safety belt in the pilot's seat facing an experimental console [2]. During the entire flight along the weightlessness parabola he was to hold onto a low-force electrodynamograph (designed by Ye. M. Yuganov, R. I. Utyamyshev and A. V. Yegorov) with a tension of 400 g. The electrodynamograph was attached to the vertical panel of the experimental console in front of the test subject at a height of 20 cm above the plane of the console. A scale covering 50 g was on the side of the electrodynamograph facing the test subject. The magnitude of the smallest graduation was 10 g. From these graduations it was determined how strongly special handles on the right and left sides of the electrodynamograph were pressed. The length of the projecting handles was 4 cm. The maximum angle of displacement of the handles was about 65°. This displacement, by means of a transmission system, actuated the disk with the susperimposed "force scale" and recorded variations in the electrical potential on an oscillograph. /170

The test subject was obliged to keep the specified force constant for 10-15 sec in horizontal flight before going into the weightlessness parabola, during the g-force period before and after weightlessness, during weightlessness, and for the first 15 sec of subsequent horizontal flight. The handle of the electrodynamograph was depressed by the thumb of the right hand without support. Skin electrodes were attached to the upper side of the joint of the thumb of the working hand in order to record the bioelectric activity of the corresponding groups of muscles.

The test subjects worked according to the instruction: "On the light signal" attention! weightlessness," which was given in horizontal flight 10-15 sec before the aircraft went into the parabola, use the thumb of the right hand to press the handle of the electrodynamograph with a force of 400 g, while watching the scale of the instrument, and keep uo this force during the entire parabola.

During the next parabola do the same thing with eyes closed. On the signal "attention! weightlessness" press on the handle with a force of 400 g, check this action visually, close your eyes and keep up this force until the aircraft leaves

*The experimental portion of the investigation was carried out under the supervision of Ye. M. Yuganov.

the parabola and gets into horizontal flight. Stop the operation on the signal "finished" in horizontal flight."

Examined were 18 males, aged 18-43. Before the start of our research the majority of the test subjects had participated several times in flights along a weightlessness parabola. Among them were the cosmonauts Nikolayev, Bykovskiy, Kamarov and Belyayev. One test subject was the first to participate in flights along a parabola. None of the test subjects had had prior experience in maintaining a force on an electrodynamograph; they received only orientative instructions 15 to 30 min before take-off of the aircraft.

The experimental results showed that it was a rather easy task for all the test subjects to maintain the specified static force during periodic transformation of the force of gravity when the task was accomplished under visual control. But /171
when visual control was excluded, the precision with which the required force was maintained depended on the degree and character of the change in weight of the test subject's body: under g-loads a tendency was observed to increase the force applied to the handle of the electrodynamograph and in weightlessness to decrease this force (Fig. 1). Over the horizontal flight sections the test subjects maintained the force with sufficient precision. This precision deteriorated each time that the magnitude of acceleration of the force of gravity deviated from 1 g. It should be especially emphasized that the force changed particularly abruptly toward the lower side during the first few seconds of transition to weightlessness. This was true of the test subject who first participated in flight along a weightlessness parabola, even with visual control (Fig. 2). As evident from the figure, it was only a very short time (5 sec) before the test subject began to carry out the experimental mission accurately.

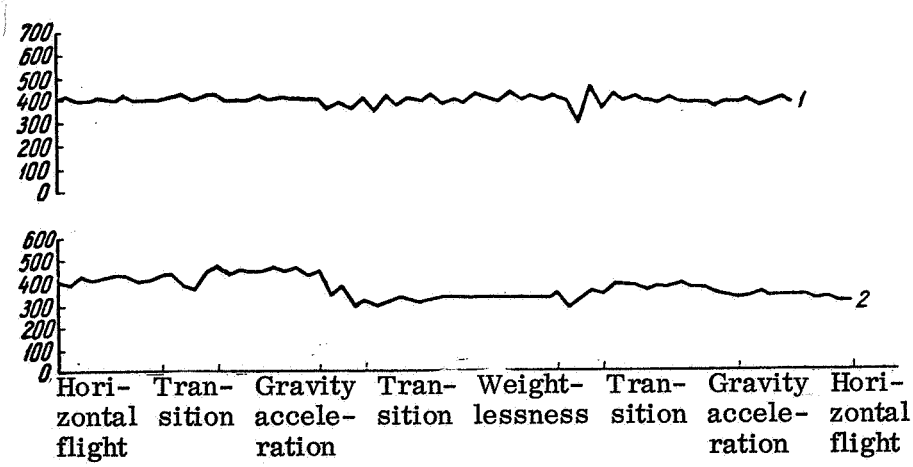

Figure 1. Graph Showing Maintenance of Force at 400 g by Test Subject With a Large Amount of Flying Experience Along Weightlessness Parabolas, With Visual Control (1) and With Eyes Closed (2).

Given in the table are the results of a statistical analysis of the data obtained when the test subjects carried out the mission with eyes closed.

From the data of the table it is evident that the magnitude of the force during weightlessness decreased as compared with the corresponding force during horizontal flight and gravity acceleration.

In horizontal flight the amplitude of oscillations of the biopotentials of the hand was minimum; it increased considerably during weightlessness (by 100-150%), but remained almost unchanged or increased only slightly in the g-force flight sections. This supports the data of our previously published work, in which the same method was used, but the test subjects who participated in it did not have /172
experience in flying over weightlessness parabolas and did not have prior fixed experimental motor skill [1]. The amplitude of the EMG oscillations during execution of the same task, but with eyes closed, was identical in all stages of change in weightlessness, but higher by 75-100% than in horizontal flight when maintaining the force with visual control.

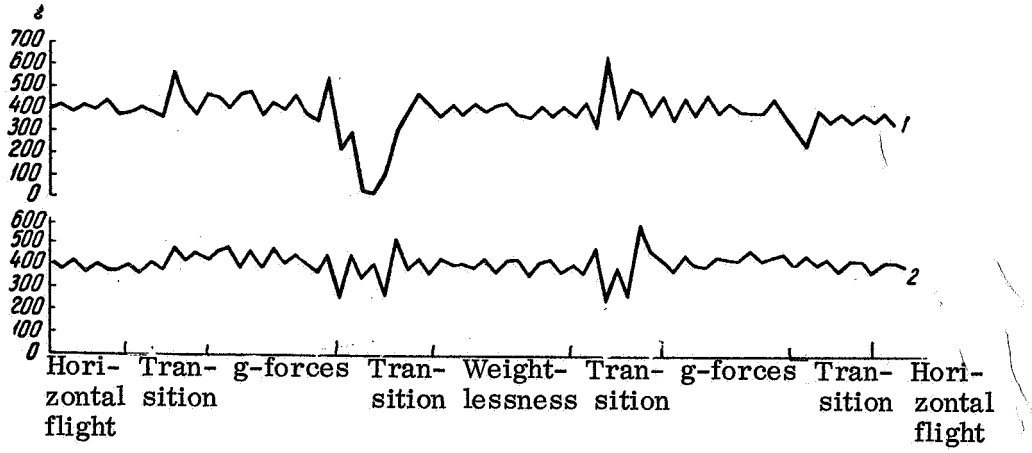

Figure 2. Graph Showing Maintenance of Force at 400 g by a Test Subject Who Was Inexperienced in Flying over Weightlessness Parabolas; With Visual Control (1) and With Eyes Closed (2).

In one series of experiments the EMG of certain posture muscles of three test subjects was recorded, in particular of the trapezius of the neck and, for comparison, of the pectoralis major.

The significance of the initial working posture for the efficiency of any motor act is well known. The posture musculature during the process of human motor activity performs specific static and dynamic work that is due primarily /173
to the effect of the force of gravity. We assumed that under the conditions of weightlessness the bioelectric activity of the posture muscles would decrease. This working hypothesis had been confirmed earlier [1], as was true also in the present experiments. A decrease in gravity to 0 g led in all test subjects to a decrease in the bioelectric activity of the neck muscles (trapezius). The electric potential of the large pectoral muscle, taken for comparison, increased somewhat during the transition to weightlessness, but remained almost unchanged during weightlessness.

Maintenance of the Required Force (in g)
By Test Subjects With Eyes Closed

Statistical index	Horizontal flight (controlled)	Gravity acceleration before weightlessness	Weightlessness	Gravity acceleration after weightlessness	Horizontal flight after weightlessness and gravity acceleration
M	383	390	367	382	367
σ	62	105	83.4	95.6	104.9
m	5.6	8.00	5.0	7.5	9.6
t		0.7	2.13	1.06	1.44

Remark. M = arithmetic mean; σ = mean square deviation; m = mean error of the arithmetic mean; t = reliability factor.

Thus, a detailed analysis of mechanograms and statistical reduction of the data revealed a stable tendency toward a change in the static force as a result of transition of the test subjects to the accelerated gravity and weightlessness states and during the time these factors are effective. It was found that the magnitude of the force reflects the overall trend of the transformation of gravity. When the body weight of the test subject increased, so did the force exerted on the handle of the electrodynamograph, if the vector of gravitational acceleration coincided with the force exerted; when the weight decreased, so did the force exerted on the handle of the electrodynamograph and the body weight. When visual control is eliminated, this relationship shows up even more distinctly.

The facts we obtained contradict the data recorded in [2]. In the experiments of these authors, which were carried out under analogous conditions and by the same method, in the state of weightlessness the test subjects, trying to maintain the specified static force, pressed on the handle of the instrument with greater, and not lesser force, as in our experiments. This contradiction is of purely external character and is explained by several peculiarities of the experiments. In particular, all the test subjects were trained to maintain the force, and they advanced to the weightlessness tests only when the experimental skill had been well ingrained in them; secondly, a dosimeter was attached to the hand and could move along with the hand; and, finally, the test subjects were not experienced in flight along a weightlessness parabola. In our experiments the test personnel only received instructions and a familarization session on how to work by the method used and were adapted to the alternating effects of gravitational acceleration and weightlessness. In other words, in our work and the cited reference, facts were obtained as to how weightlessness affects the level of the static force in trained and untrained test personnel. In the trained test subjects of [2] the acceptor of the action had been formed, whereas in our test subjects it had not yet taken shape. The presence of an action acceptor with reinforced kinesthetic components in all the test subjects caused a lapse of adequate stimulation during weightlessness, resulting in compensatory activation of the muscle groups which participated in execution of the experimental task. Thus, there was a lack of a model of the nervous stimulus, i.e., of the sensory standard which, by collating the standard with the structure and character of inverse afferentation, would have /174

signaled that the task had been successfully completed. However, the mentioned phenomenon was complicated by the process of forming an action acceptor. It is completely obvious that proprioreception played a part in the formation of an action acceptor, both in the familiarization session as well as in the first stages of flight, when the given force was maintained under visual control. This is testified to by the nonuniformity of the static force during transitions from gravitational acceleration to weightlessness and, conversely, from weightlessness to gravitational acceleration, as well as by the increase in the bioelectric activity of the muscles of the working hand.

There is all reason to believe that this phenomenon is caused by a change in the character of the experimental activity of the test subjects. According to the instructions, the test subjects were to maintain a given force exactly, consciously counteracting any impulse to change this force, This was comparatively easy for them in the period of horizontal flight - the corresponding curves of the mechanograms of maintenance of forces coincide sufficiently closely with a straight line. In the transitional periods the mechanograms take on the character of a broken line; the static forces of the test subjects are complicated by dynamic components. It can be assumed that this explains in a certain measure the increase in the bioelectric activity of the muscles. Moreover, in connection with the vanishing weight it is possible that it was necessary to develop additional muscular force of the hand to compensate the pressure on the handle of the electrodynamograph, pressure which was generated during horizontal flight by the weight of the hand. In order to make this hypothesis more precise, we conducted a series of experiments with the arm fixed at the elbow and radiocarpal joints, thus preventing weight from contributing to pressure on the handle of the dynamograph. The results turned out the same as before, namely, the bioelectric potential of the muscles increased. Finally, it is incontestable that general orientative reaction to changes in weightlessness also participated in the genesis of this phenomenon. In other words, the reason for the increase in bioelectric activity of the arm muscles in our experiments is manifold.

The affect of gravitational acceleration and weightlessness as a stress factor and an external inhibitor leads to a reduction of control by the test subject of the execution of his experimental task. It was demonstrated in the work of A. S. Yegorov and Yu. Z. Zakhar'yants that in the case of identical motions, the biopotential of the respective muscles increased with a reduction in control by the test subject of the motion to be executed, forfeiting the inherent stability in the presence of control This position of the authors is also confirmed by our observations of the maintenance of force on the electrodynamograph with eyes closed. In this case the bioelectric activity was the same during horizontal flight, gravitational acceleration and weightlessness, but higher than when performing the same task with eyes open, whereas when performing the task with visual control the biopotential increased sharply only during weightlessness. /175

In our experiments all conditions for performing the action without the usual control by the test subject when he entered the situation of alternating effects of gravitational acceleration and weightlessness were less habitual than the conditions of horizontal flight.

The above-outlined characteristics of the effect of transformation of gravity on the magnitude of static force has a pronounced individual character in test

subjects. In all the test subjects, however, we detected a stable tendency toward progressively more exact execution of the task under changing flight conditions.

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